

Review on Heat Transfer Enhancement by Coiled Tube

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Abstract

In order to develop highly efficient, low cost, lightweight, and small heat exchangers, the analysis of heat transfer enhancement has always been an interesting topic in the scientific community. In terms of thermal performance characteristics, this paper reviews the investigation of heat transfer enhancement by coiled tubes. It is founded that the heat transfer rates on the external side of a coiled tube are higher than the internal side of a coiled tube and the addition of few amounts of nanoparticles (Al₂O₃) significantly increases the heat transfer performance up to 1%. The study also summarizes that the best heat transfer characteristics of nanofluid were achieved when it flows through a coiled tube rather than a straight tube and Al₂O₃ nanofluid provides better performance in the heat transfer enhancement than that of CuO nanofluid in coiled tubes. It is also found that the turbulent heat transfer coefficient in the air could be achieved as much as two times higher and the effectiveness could be achieved as much as two times higher when compared with a straight tube for Reynolds number ranging from 20000 to 45000. In addition, the heat transfer coefficient in the air could be achieved as much as two times higher and the effectiveness could be achieved as much as 1.25 times higher when compared with a straight tube for low Reynolds number ranging from 6000 to 22000.

Keywords: - *Heat transfer enhancement, Straight tube, Coiled tube, Nanofluids, Effectiveness.*

INTRODUCTION

For increasing the transfer of heat efficiency, using passive techniques are an important topic for scientists and researchers during recent decades. Various numerical and experimental studies have been accompanied for improving heat transferred by these techniques.

The demand to reduce the cost and size of the heat exchanger has influenced the researchers to investigate different ways of heat transfer enhancement techniques. According to **Tabatabaeikia et al. [1]**, the techniques of passive heat transfer enhancement are mostly preferred because of their simple and applicable nature in many applications. The passive techniques of heat transfer enhancement commonly reduce the thermal resistance rather than the active heat transfer technique by achieving or by creating a swirl of the fluid, which is flowed through the tubes.

Various kinds of tube coils are mostly used to increase the heat transfer rate, which shows that the increased flow rates and increased surface contact areas for small distances. Moreover, the helical coiled tubes, spirally coiled tubes, curved tubes and other modified coiled tubes are most used for enhancing the heat transfer in heat exchangers [1].

COILED TUBE

Helical coils are widely used for compactness and high heat transfer coefficient (HTC) as heat exchangers such as steam generators. It is used in chemical industries for mixing and cooling, waste heat recovery processes, cryogenic processes and biomechanical engineering fields [2]. **Figure 1** showed the schematic diagram and cross-section of the coiled tube in the tube heat exchanger [3].

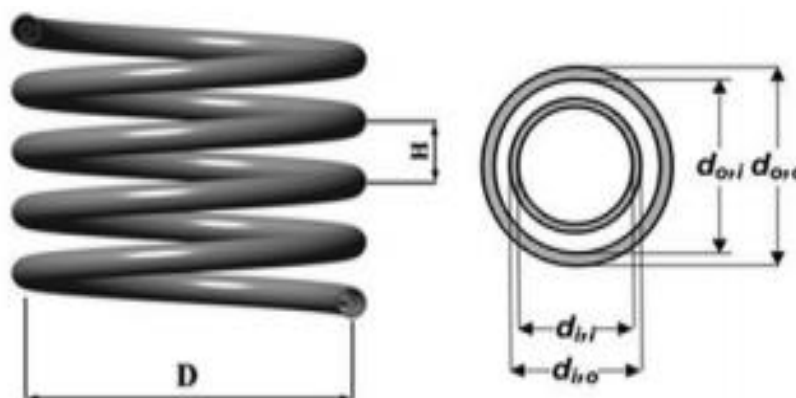


Figure 1: Schematic diagram and cross section of coiled tube heat exchanger [3].

Jayakumara et al. [2] experimented with the heat transfer enhancement of helical coil tubes and found that the performance of the heat transfer rate of the coiled tube is higher than the corresponding straight tubes.

Along with the length for the tubes, the Nusselt numbers at various points was estimated and the highest Nusselt number on the external side of the coil is found as higher among all other points at a specified cross-section of tubes, where the internal side of the coils Nusselt number is found as lowest.

Their investigations figure out the change of local Nusselt number as well as the variation of length and circumference of the helical tubes walls and CFD simulations are also conducted for helical coils which are vertically oriented by varying coil parameters such as pitch circle diameter, coil pitch and coils diameter to study their influence on heat transfer augmentation process.

Figure 2 illustrates the variation for local Nusselt number as a function of angular position and average Nusselt number for constant q_w boundary conditions [2].

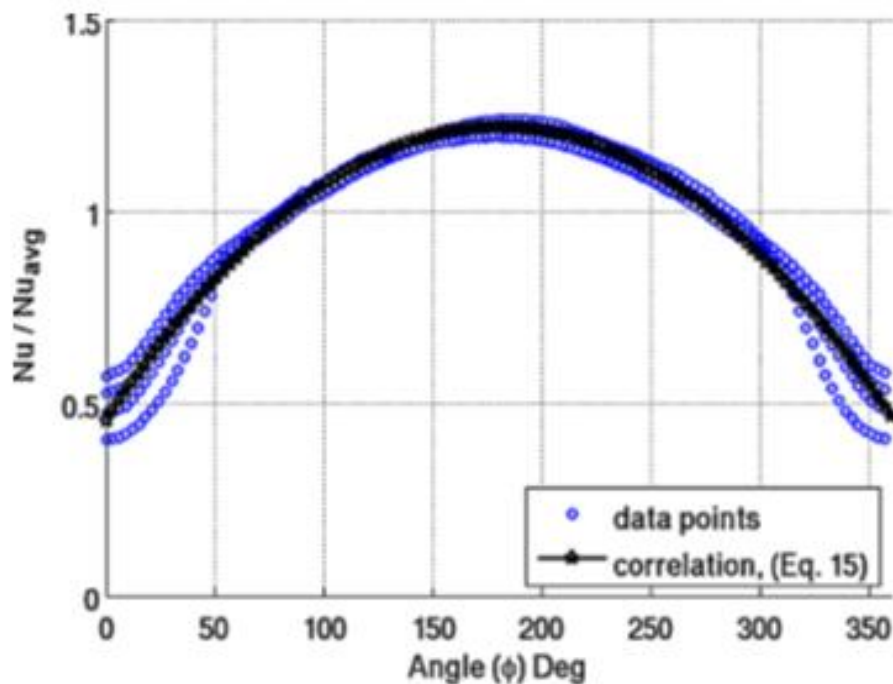


Figure 2: Variation of local Nusselt number as function of angular position and average Nusselt number for constant q_w boundary condition [2].

Sasmito et al. [4] proposed a simultaneous passive heat transfer enhancement by combining the modified geometry of coils and nanofluids and found that the addition of few amounts of nanoparticles increases the heat transfer up to 1% in performance. Water-Al₂O₃ and water-CuO as suspensions of nanofluid are examined in this study. The flow behavior and heat transfer performance with nanofluids in various geometries such as coiled square tubes, conical spiral, helical spiral and in-plane spiral are compared and examined with those which are flowing with water in a straight tube [4]. See **figure 3**.

Akbaridoust et al. [5] illustrated the pressure drop along with the convective heat transfer behavior of nanofluids and compared between experimental and

numerical results. The coils with greater curvature ratio provide higher thermal performance for a specific curvature ratio range. The study also revealed that the use of base fluid in a coiled tube with increased curvature and compared it with the utilization of nanofluid in straight tubes and found more effective heat transfer enhancement. This result was observed for heat transfer characteristics of nanofluid, which is found as the best heat transfer is achieved when it flows through the coiled tube compared with a straight tube. **Figure 4, Figure 5 and Figure 6** showed the velocity profiles of axial for Reynolds number, effects of curvature ratio on axial velocity in helical pipes and effects of Reynolds number on axial velocity in helical pipes, respectively [5].

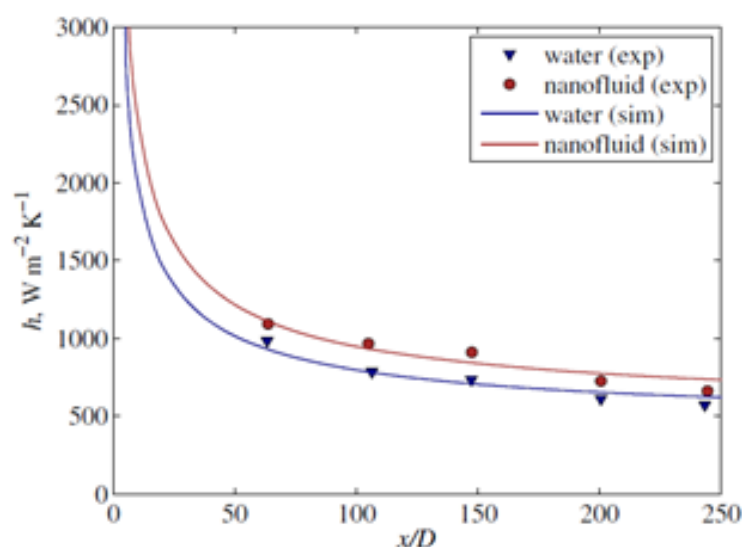


Figure 3: Comparison of HTC for water and nanofluid between simulation (lines) and experimental data (symbols) [4].

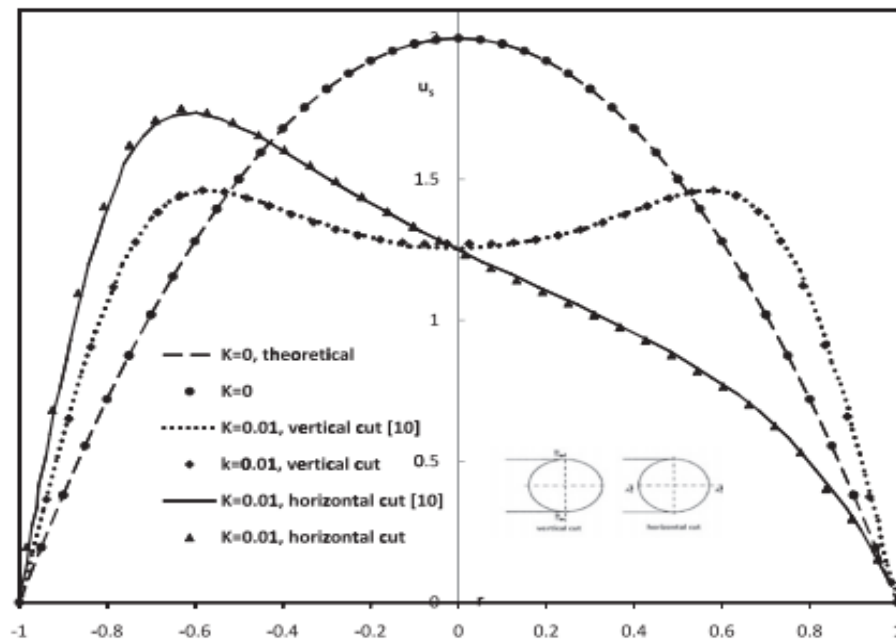


Figure 4: Axial velocity profiles for $Re=1000$, $\tau=0$, $K=0.01$ [5].

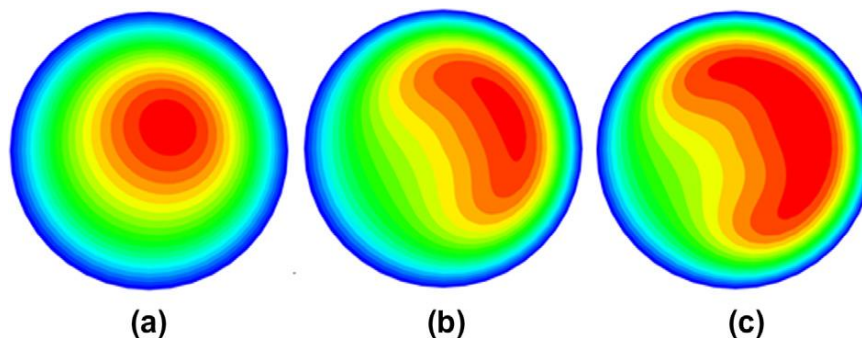


Figure 5: Effects of curvature ratio on axial velocity in helical pipes (a) $K=0.01$; (b) $K=0.1$; (c) $K=0.25$ [5].

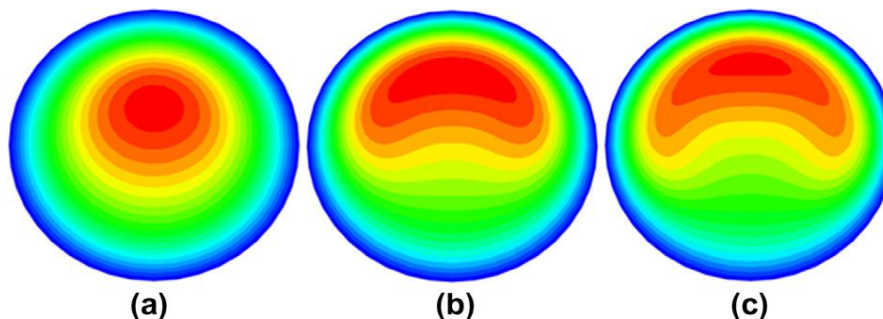


Figure 6: Effects of Reynolds number on axial velocity in helical pipes $K=0.01$ (a) $Re=200$; (b) $Re=600$; (c) $Re=1000$ [5].

Aly [6] conducted a CFD simulation to study the heat transfer enhancement and pressure drop characteristics of water-based Al_2O_3 nanofluids, which are flowing through a coiled tube in tube heat exchangers and found that the different behavior on the parameters was selected for the compared with the base fluid.

Moreover, the comparison at the same Re or Dn , the heat transfer efficiency, is increased by developing the coil diameter and nanoparticles volume concentration as well. The factor of friction increasing also with the increase in curvature ratio and pressure drop penalty is negligibly high nanoparticle volume concentration.

Figure 7 illustrates the comparison in simulated values of (a) Nusselt number and (b) predicted friction factors [6].

Sarkar et al. [7] experimentally investigated the enhancement of turbulent heat transfer flow of air through one smooth tube and four different tubes with wire-coil inserts (Pitches, $P_c = 12, 24, 40$, and 50 mm with corresponding helix angles, $\alpha = 10^\circ, 20^\circ, 35^\circ$, and 45° , respectively) at Reynolds numbers ranging from 20000 to 45000 . It is observed from the research that the turbulent flow heat transfer coefficient is two times higher and the effectiveness as much as two times higher than those for the straight tubes with similar flow patterns [7].

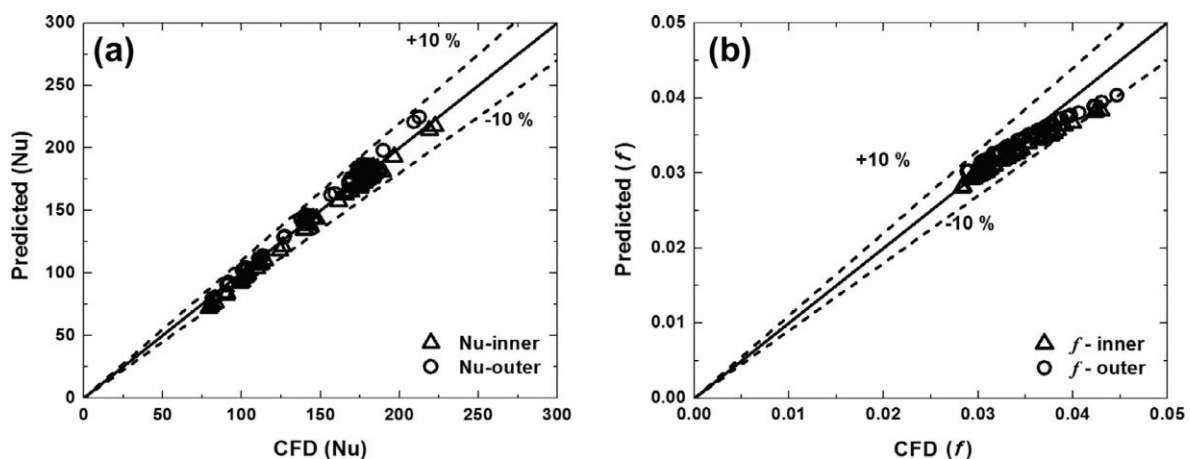


Figure 7: The comparison of the simulated values of (a) Nusselt number (b) Predicted friction factors [6].

For low turbulent flow heat transfer enhancement along with the effectiveness of the heat exchangers, there is very little literature available in the scientific community. Therefore, Abedin and Sarkar [8] recently experimented with the enhancement of turbulent heat transfer flow of air through one smooth tube and four different tubes with wire-coil inserts (Pitches, $P_c = 12, 24, 40$, and 50 mm with corresponding helix angles, $\alpha = 10^\circ, 20^\circ, 35^\circ$, and 45° , respectively) at low Reynolds

numbers ranging from 6000 to 22000. It is observed from the research that the turbulent flow heat transfer coefficient is two times higher and the effectiveness as much as 1.25 times higher than those for the straight tubes with similar flow patterns, which is illustrated in **Figure 8(a)**. It is also proposed a correlation of predicted swirl heat transfer coefficients inside the tubes at low Reynolds numbers showed in **Figure 8(b)** [8].

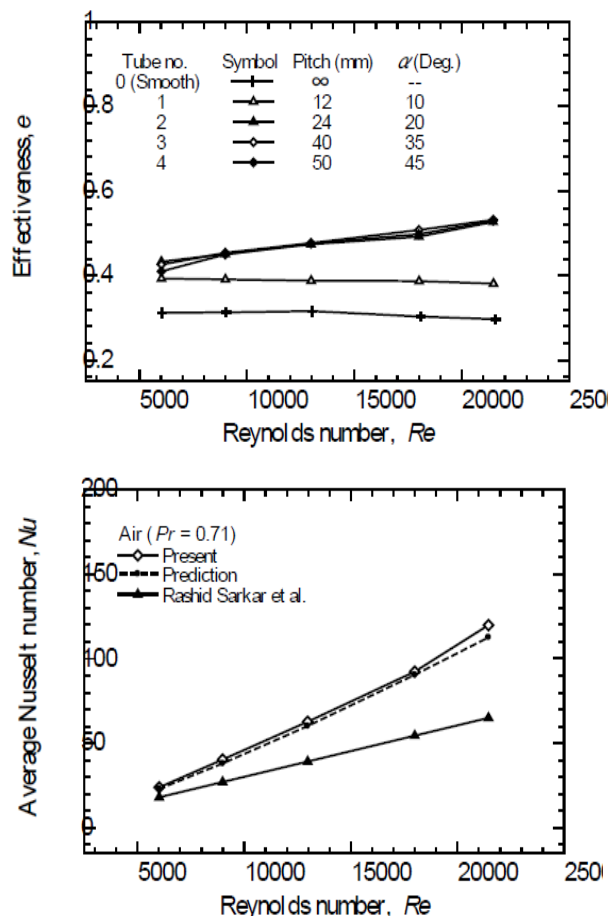


Figure 8: (a) Variation of average effectiveness against Reynolds number for straight tube and wire coil inserted tubes. (b) Predicted heat transfer coefficients for wire coil inserted tube (Pitch = 50 mm, helix angle, $\alpha = 45^\circ$) [8].

SUMMARY

Heat transfer enhancement with a coiled tube has a significant role in recent research and studies. This study reviews the thermal performance characteristics of the coiled tube in different mediums. It is also found that the heat transfer in a coiled tube is higher than in a corresponding straight tube. Nusselt number on the external side of the coil is maximum among all the other points at a specified tube cross-section while it is lowest at the internal side of the coil. It is also revealed that the combinations of small amounts of nanoparticles (Al_2O_3) and the geometry effects increase the heat transfer performance up to 1% and Al_2O_3 nanofluid provides better performance in the heat transfer enhancement than that of CuO nanofluid in coiled tubes. Moreover, the best heat transfer characteristics of nanofluid were achieved when it flows

through a coiled tube with a greater curvature ratio rather than a straight tube and the heat transfer coefficient increases by increasing the coil diameter and nanoparticles volume concentration. It is also found that the turbulent heat transfer coefficient in the air could be achieved as much as two times higher and the effectiveness could be achieved as much as two times higher when compared with a straight tube for Reynolds number (Re) ranging from 20000 to 45000. In addition, the heat transfer coefficient in the air could be achieved as much as two times higher and the effectiveness could be achieved as much as 1.25 times higher when compared with a straight tube for low Reynolds number (Re) ranging from 6000 to 22000. The heat transfer enhancement by a coiled tube with different conditions is illustrated in **Figure 9**.

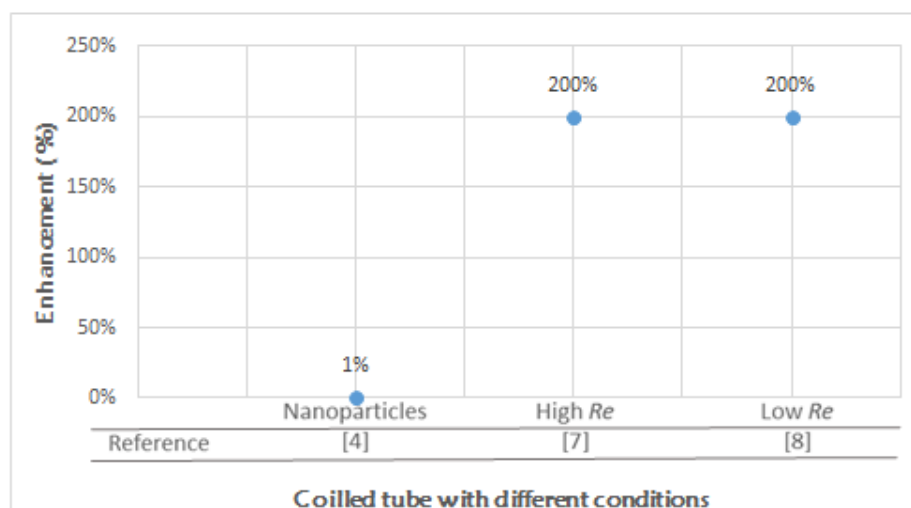


Figure 9: Heat transfer enhancement by coiled tube with different conditions.

CONCLUSION

The study about the effect of a coiled tube on heat transfer characteristics has been reviewed. Different types of coiled tubes in various mediums and arrangements have been considered. The main conclusions can be briefly drawn as follows.

1. Nusselt number, i.e., the heat transfer rates on the external side of the coil, is found as the highest among all other points at a specified cross-section of a coiled tube, where the internal side of the coil is the lowest.
2. The addition of few amounts of nanoparticles (Al_2O_3) significantly improves the heat transfer performance up to 1%.
3. The best heat transfer characteristics of nanofluid were achieved when it flows through a coiled tube rather than a straight tube and Al_2O_3 nanofluid can provide better performance in the heat transfer enhancement than that of CuO nanofluid in coiled tubes.
4. The heat transfer coefficient (HTC) can be increased by increasing the diameter of the coil and nanoparticles volume concentration.
5. The turbulent heat transfer coefficient in the air could be achieved as much as two times higher and the effectiveness could be achieved as much as two times higher when compared with a straight tube for Reynolds number ranging from 20000 to 45000.
6. The heat transfer coefficient in the air could be achieved as much as two times higher and the effectiveness could be achieved as much as 1.25 times higher when compared with a straight tube for low Reynolds number ranging from 6000 to 22000.

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